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REFRIGERATOR CAR HEATING

by

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Report of Investigations Conducted
by the Office of Preservation of
Fruits and Vegetables in
Transit and Storage.

1921

Bureau of Markets and Crop Estimates
U.S. Department of Agriculture
Washington, D. C.

REFRIGERATOR CAR HEATING

For a number of years investigations have been carried on by the Bureau of Markets of the United States Department of Agriculture, with reference to the prevention of freezing of fruits and vegetables in transit. The investigations first undertaken centered chiefly in the effectiveness of insulation as a protective measure, and sought to develop a system of heating which would enable the heat to be equally distributed throughout the car and would avoid injury of the fruit from irregular temperatures or other causes. Should an efficient heater car be developed immediately, it would still be a number of years before such equipment could be placed in actual service. In the meantime it is essential that methods of heating be developed whereby the present unsatisfactory equipment may be made more effectual.

It is difficult to ascertain the amount of money paid by the railroads in claims for freezing of perishable food products in transit. However, the following statement prepared by the Freight Claim Division of the American Railway Association indicates the extent of the losses from freezing sustained by the railroads:

"Our monthly report of claim payments, separated as to cause and commodities, was not inaugurated until September, 1920. Our classification carries under "Causes" an item entitled "Freezing or Heater Failure" and for the last four months in 1920 payments were reported to us of $456,143.00 on carload shipments and $59,003.00 on less carload shipments. Using these figures as a basis and approximating the total freight loss and damage claim payments for the year 1920 as $109,000,000, we

estimate that there was lost during that year an amount of $1,853,000.00, account of "Freezing or Heater Failures," or 1.7 per cent of the total mentioned. Of course, the large part of the payments for this cause is chargeable to the business of the winter of 1919-20, as such claim payments are very seldom made in the same month that the damage occurred. For the first two months in 1921 similar payments are quoted to us as follows:"

"	CARLOAD	LESS CARLOAD "
January -	$128,288.00	$11,004.00
February -	95,656.00	9,394.00

The presence of frozen fruits and vegetables in trade channels has a very demoralizing effect on market prices of the products that are not frozen. Such losses have been noted practically every severe winter. The prevention of this waste in the shipment of perishable food products is one of the serious transportation problems confronting the railroads and agricultural interests.

FUNDAMENTAL PRINCIPLES OF REFRIGERATOR CAR HEATING

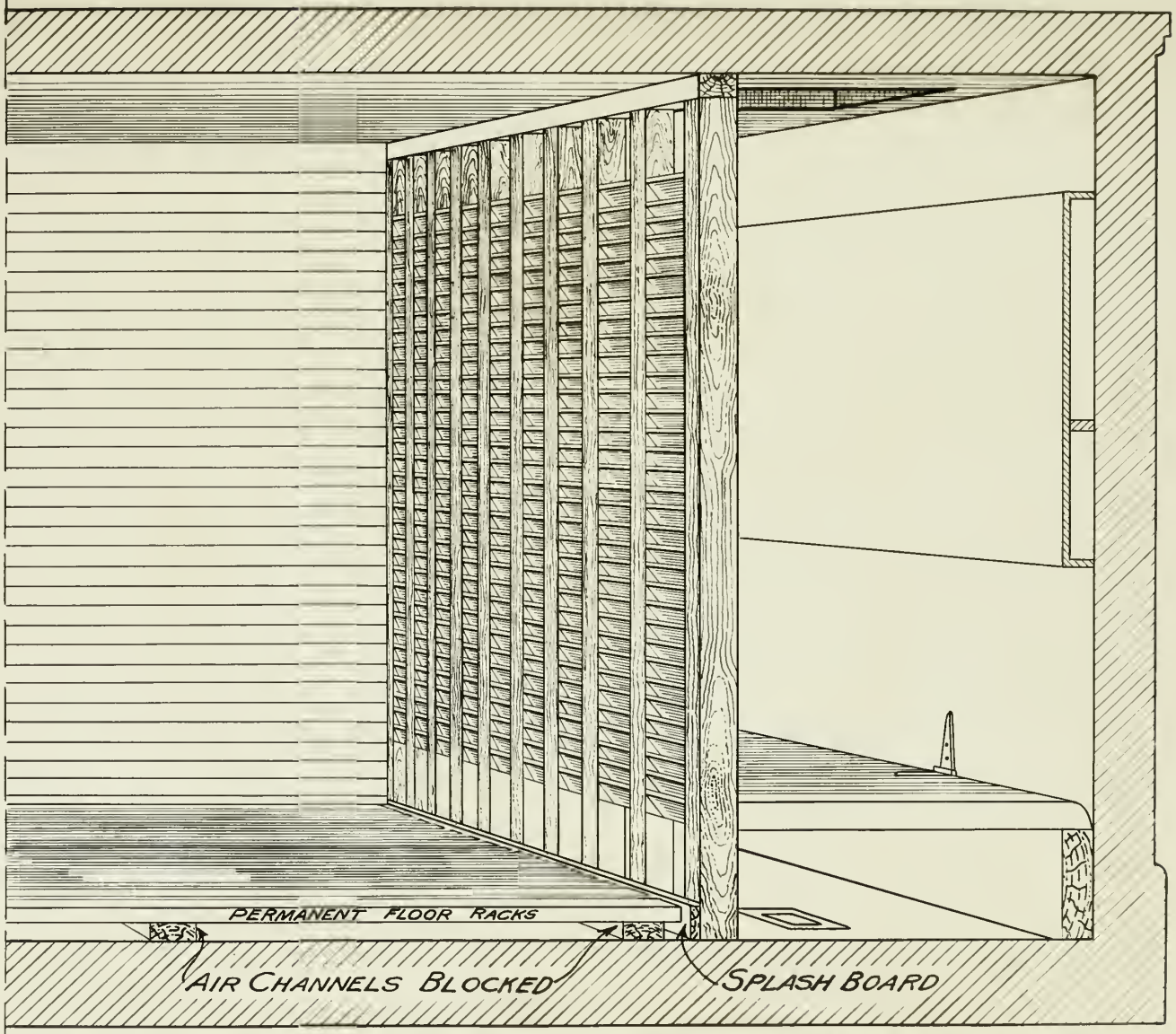
This preliminary report is concerned only with a discussion of the simple principles of refrigerator car heating. In the use and construction of a large part of the refrigerator car equipment in service at the present time, the fundamental principles of the movement of hot and cold air seem to have been overlooked. Cold air may enter through drain pipes, around doors, through loose hatch-plugs, and broken insulation in any part of the car. It seeks and occupies the lowest level, creating the coldest area along the floor. Warm air from a heater rises immediately to the ceiling and passes from the bunker over the top of

the load. This air is replaced by colder air from the lower levels, which in turn is heated and passes out of the bunker, setting up a circulation of the air within the car. It is this air circulation which eventually warms the car floor and prevents freezing of the lading. To be effective, it must be uniform and rapid. The rate of circulation is most rapid when the path through which it moves is free from obstructions.

Most of the heaters now used in the Carriers' protective service are entirely adequate to furnish sufficient warm air to protect the lading in refrigerator cars from freezing, but their efficiency is lowered by faulty car construction and the use of improper loading methods which prevent an adequate circulation of the air.

Figure 1 illustrates (1) a common fault in bulkhead construction; (2) a faulty floor-rack construction. It will be noted that while this is an open type of bulkhead permitting short circuiting of the air currents passing to and from the bunker, a high splashboard is also constructed at the bottom of the bulkhead, the same height as the floor-rack. While the heaters are burning, this splashboard blocks to a considerable extent the movement of air from underneath the load into the bunker.

The floor-rack is so constructed that it defeats its own purpose. Instead of providing channels lengthwise of the car for the air to move in, all such channels are blocked by the transverse supporting strips. See A.A. Fig. 1. When the car is loaded there is no opportunity for air to move freely under the floor-rack, and the circulation is further



RELATIVE HEIGHTS OF SPLASH-BOARD AND FLOOR RACK, ALSO THE BLOCKING

checked by the high splash-board. It can readily be seen that heaters placed on ice grates as high as shown by this illustration would draw the cold air from a plane 24 to 27 inches above the floor of the car. Any perishable produce placed in this area below the plane of the heater flame would be in the danger zone with the probability of freezing in severe weather. Provisions must be made for the circulation of warm air.

Figure 2 illustrates another type of construction which is found as often, if not more often, than the one illustrated in Figure 1. In this type of bulkhead a metal brace 6 inches high extends across the bottom of the bulkhead in addition to the regular splash-board. Here again the air circulation is blocked, even with an additional temporary 5 inch floor-rack placed on top of the permanent floor-rack. The sectional side view of a car shown in Figure 3 illustrates how effectively the air movement is blocked by these two details of construction.

SCOPE OF INVESTIGATIONS

With these facts in mind, during the investigations in the winter of 1920-1921 special attention was devoted to the methods of applying and circulating heat, with a view to determining the most practical way of utilizing the present refrigerator car equipment; and, if possible, of increasing its efficiency in the protection of perishable commodities from freezing or over-heating.

Of the three test trips made during the winter of 1920-1921, only one encountered moderately severe temperatures. This trip was run from Wenatchee, Wash., to St. Paul, Minn., over the Great Northern Railway during the period of December 15 to 22 inclusive.

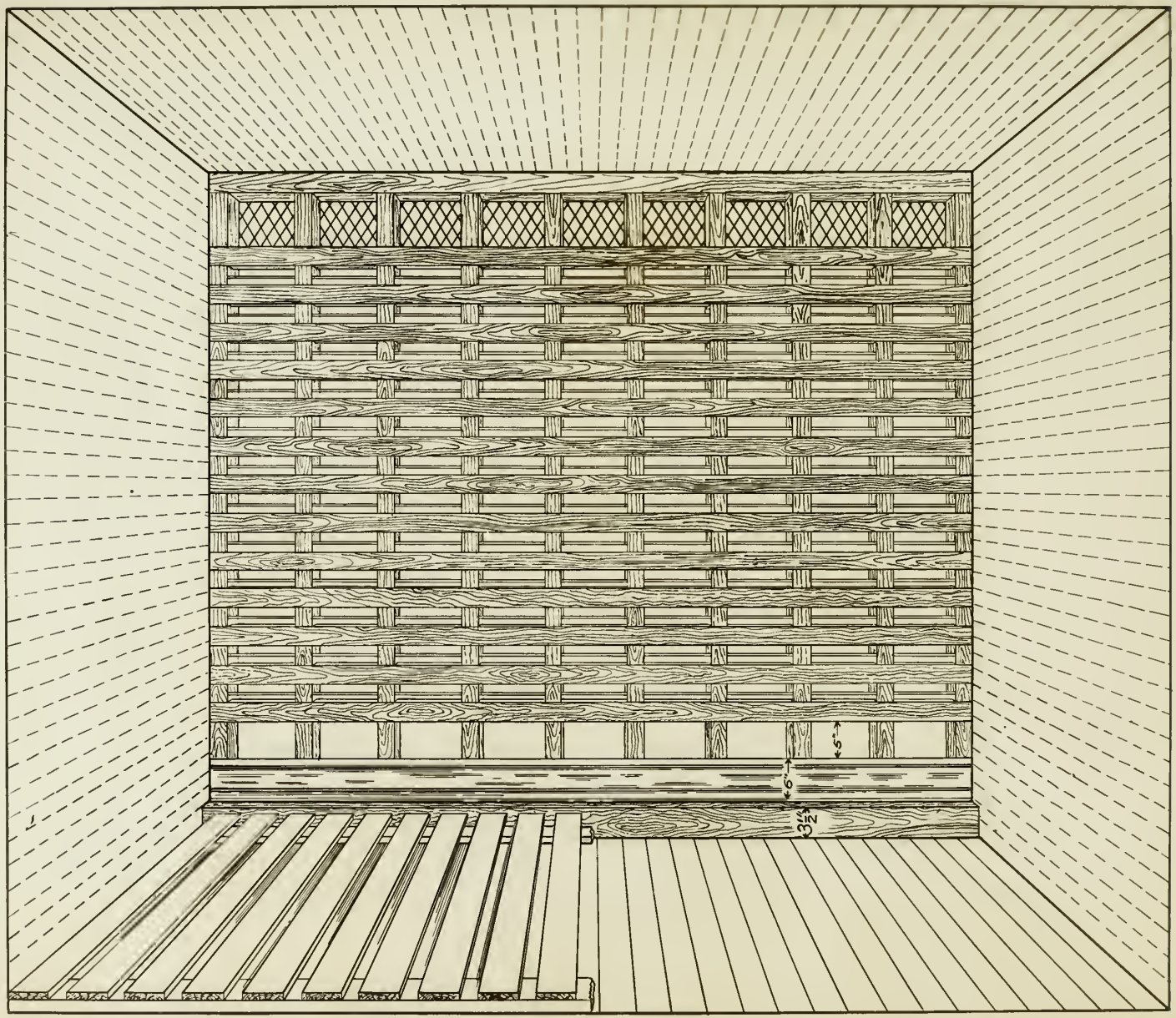


FIGURE 1 - INTERIOR VIEW OF CAR SHOWING A TYPE OF BULKHEAD IN COMMON USE. BESIDES THE REGULAR 4-1/2 INCH BRACE, THIS BULKHEAD IS PROVIDED WITH A FLAT METAL BRACE SIX INCHES HIGH, EXTENDING ACROSS BOTTOM OF BULKHEAD, BLOCKING AIR CIRCULATION AT THIS POINT.

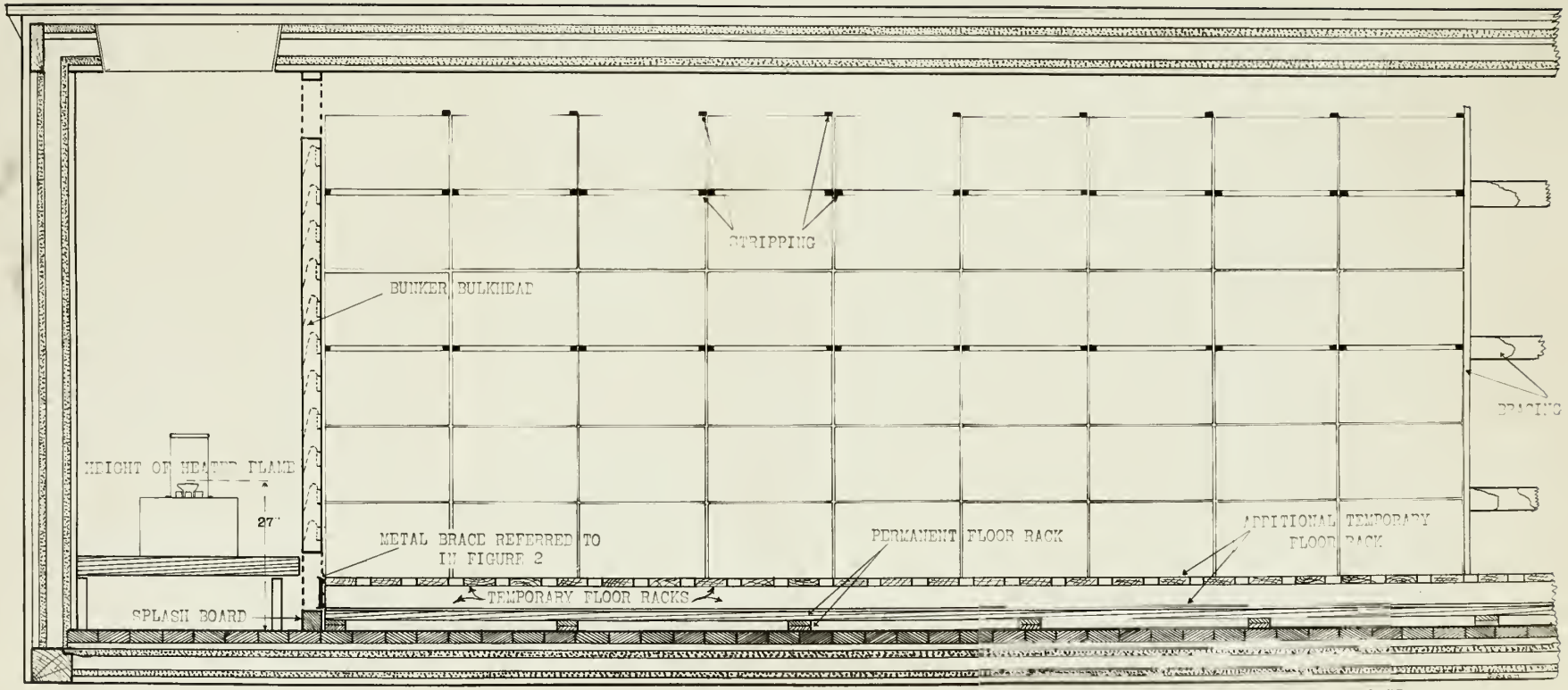


FIGURE 3 - LENGTHWISE SECTION OF REFRIGERATOR CAR SHOWING THE TYPE OF BULKHEAD ILLUSTRATED IN FIGURE 2. NOTE HIGH SPLASH BOARD AND FLAT METAL BRACE AT BOTTOM OF BULKHEAD, EFFECTIVELY PREVENTING AIR MOVEMENT FROM UNDERNEATH FLOOR RACKS [illegible] BUNKER, EVEN WITH TEMPORARY FLOOR RACKS INSTALLED ON TOP OF PERMANENT RACKS.

The cars used in this test were identical in construction, had equivalent amounts of insulation, were built in the same year, and all were loaded with boxed apples.

FLOOR RACKS

All cars were equipped with permanent floor-racks. These racks were constructed by laying 1-3/4" x 4-1/2" boards crosswise of the car on top of which 1-3/4" x 2-3/4" boards were placed lengthwise of the car. (See Figs. 1 and 2) These racks were built in five sections and hinged to the side walls. Additional temporary racks were also used in some of the cars. These were constructed of five 2" x 4" boards placed lengthwise of the car with 1" x 6" boards on top, placed crosswise of the car, built in five sections.

METHODS OF LOADING

In order that new features of loading might be carefully checked and compared with methods commonly used, one car was loaded in the regular commercial way equipped with permanent floor-racks and without paper. (See Car A Fig. 4, half load). Heaters were placed on the ice grates so as to allow flames to be within 27 inches of the floor of the car. In this car the floor-rack was the same height as the splash-board. The number of boxes in the car was 756.

Car B is shown in Figure 5. This car is equipped with an additional 4 inch floor-rack which clears the splash-board, permitting free movement of the air from under the load to the heater. A false form, replacing the first layer of boxes adjacent to the bunkers in each end of the car was installed to provide an open throat, thus giving still

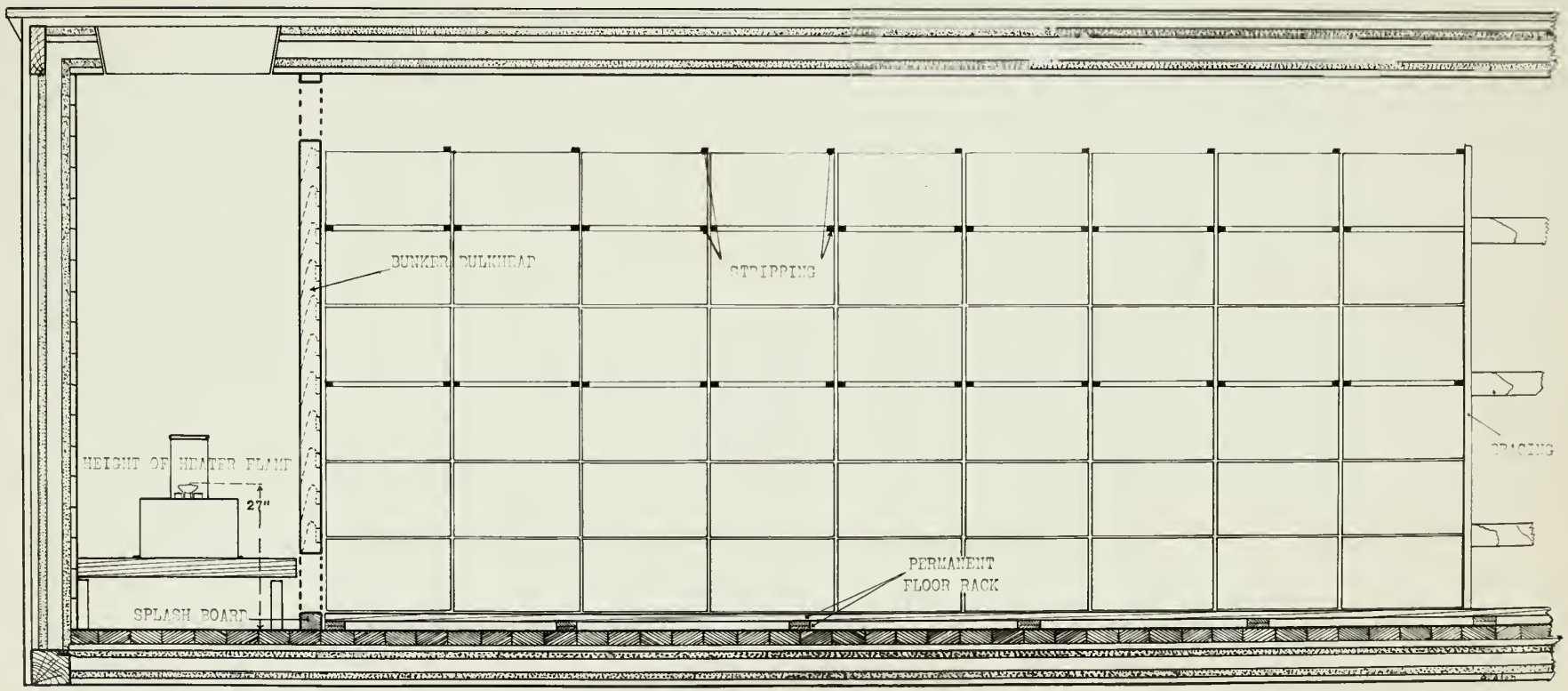


FIGURE 4 - ARRANGEMENT AND MANNER OF LOADING CAR A FOR THE TEST OF DECEMBER 1920. THIS CAR WAS LOADED IN THE REGULAR COMMERCIAL WAY AND USED AS THE CHECK CAR FOR THE TRIP. NO PAPER, NO ADDITIONAL FLOOR RACKS, AND HEATER ON THE ICE GRATE AT A HEIGHT OF 27 INCHES FROM THE FLOOR.

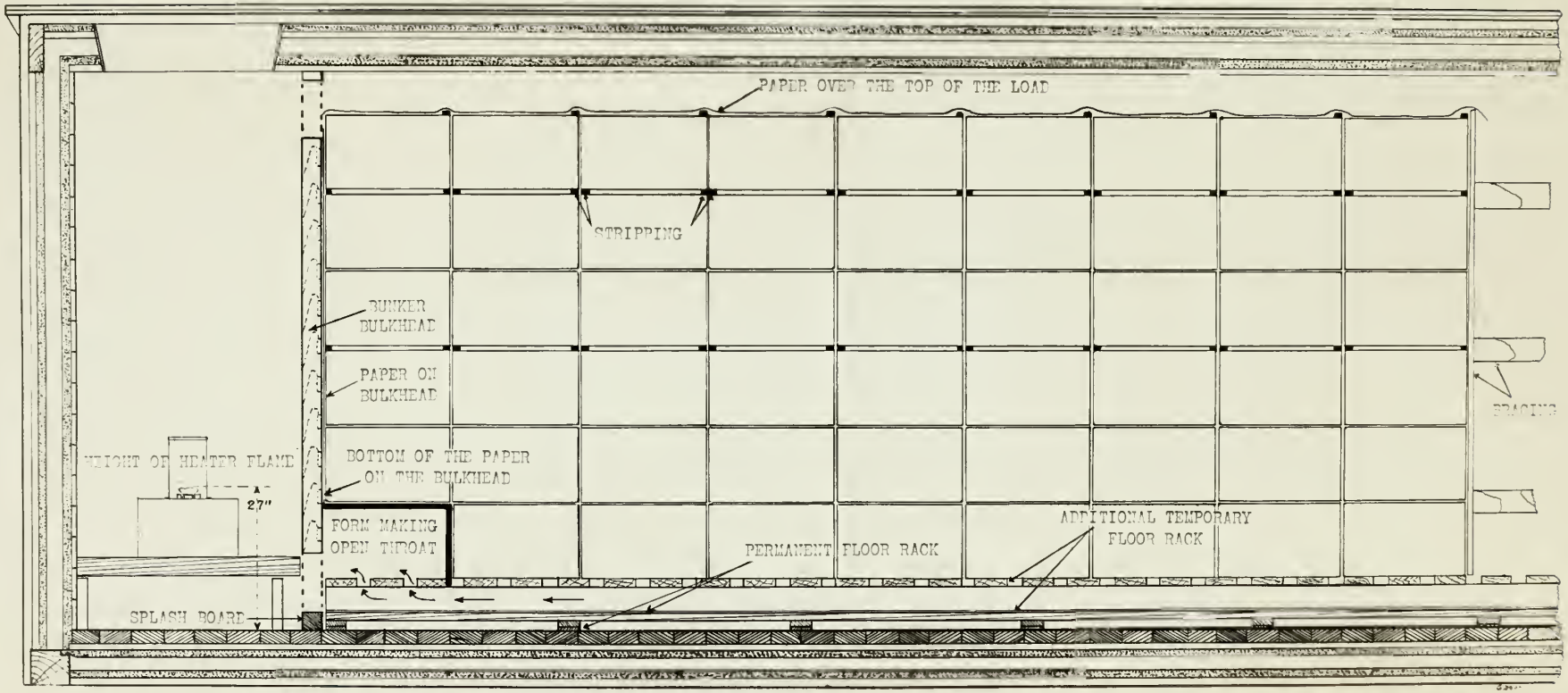


FIGURE 5 - ARRANGEMENT AND MANNER OF LOADING CAR B FOR THE TEST OF DECEMBER 1920. ADDITIONAL FLOOR RACK, AN OPEN THROAT PROVIDED BY A FALSE FORM THE HEIGHT OF THE FIRST LAYER OF APPLE BOXES ADJACENT TO THE BOTTOM OF THE BUNKER. BULKHEAD PAPERED FROM THE BOTTOM OF THE TOP OPENING TO THE TOP OF THE BOTTOM OPENING OR FALSE FORM. PAPER ACROSS THE TOP OF THE LOAD FROM WALL TO WALL.

greater opportunity for the air to get back to the heater. Paper was placed against the bulkheads extending from the bottom of the top opening near the ceiling of the car, down to the false form. Paper was also placed across the top of the load and lath strips were used to tack the paper in place against the side walls. The paper was not nailed to the lading and extended over the load only to the space between the bracing. The heaters were placed on the ice grates. The cars were loaded with 742 boxes of apples.

Car C as shown in Figure 6 is also equipped with a temporary 4 inch floor-rack placed on top of the permanent floor-rack. Additional paper was placed directly on the floor-rack but not permitted to extend between the bracing. The ice grates were raised against the walls and the heaters were lowered to the floor of the bunker, thus bringing the top of the flame 17 inches nearer the floor of the car. The load of this car was 756 boxes.

Car D is shown in Figure 7. The only difference between this method of loading and that shown in car C is in the height of the heaters from the car floor.

Car E is shown in Figure 8. Note additional 4 inch racks on top of the permanent floor-racks. NO PAPER was used except on the bunker bulkheads. Heaters were placed on the ice grates. The load was 756 boxes.

METHODS OF OBSERVATION

Fruit and air temperatures were obtained at 12 different points within each car by electrical resistance thermometers. Fruit tempera-

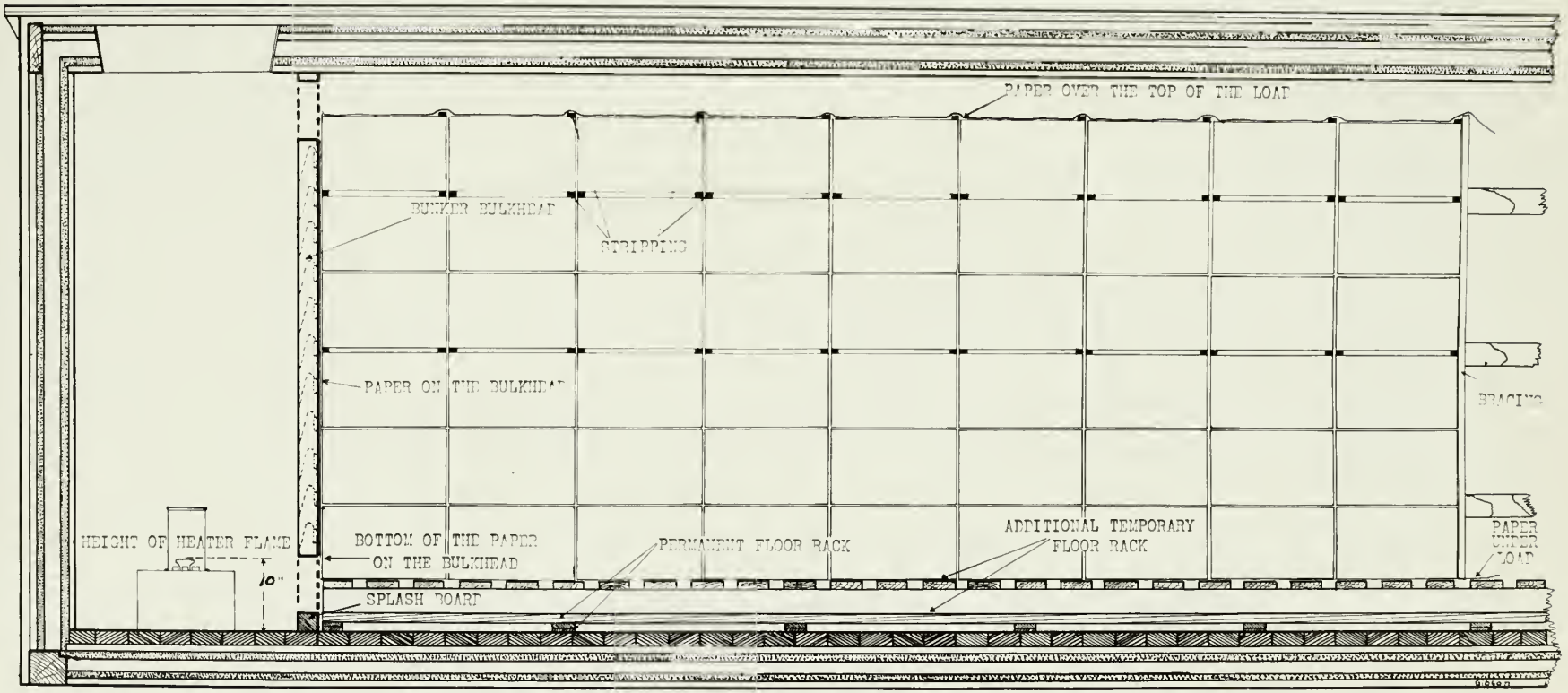


FIGURE 6 - SHOWING THE ARRANGEMENT AND THE MANNER OF APPLYING THE HEAT IN CAR C IN THE TEST RUN DURING DECEMBER 1920. ADDITIONAL FLOOR RACK, LOAD PAPERED OVER THE TOP AND DIRECTLY UNDERNEATH ON THE FLOOR RACK, AND THE BULKHEAD PAPERED BOTTOM OF THE TOP OPENING TO THE TOP OF THE BOTTOM OPENING, AND THE HEATER LOWERED TO THE CAR FLOOR.

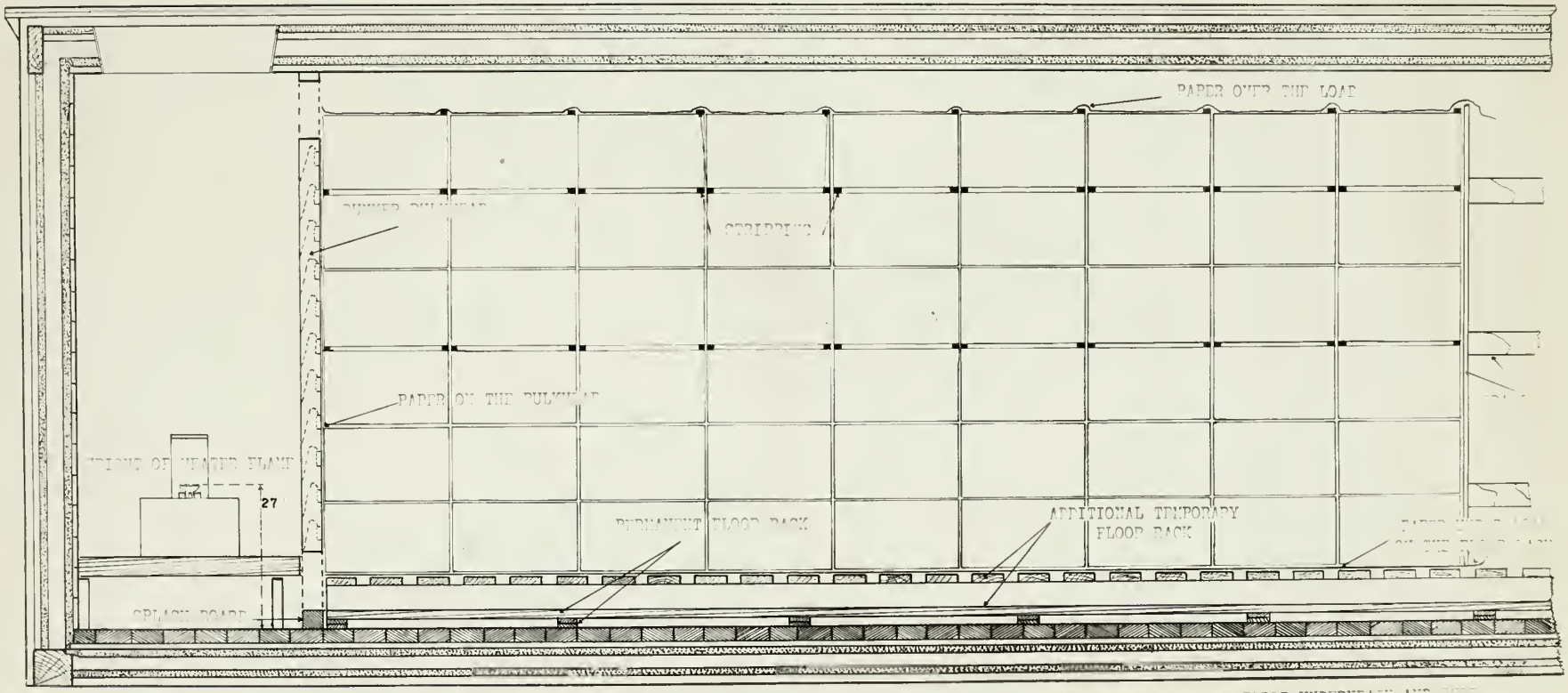


FIGURE 7 - ARRANGEMENT AND MANNER OF LOADING CAR E FOR THE TEST RUN IN DECEMBER 1920. ADDITIONAL FLOOR RACKS, LOAD PAPERED UNDERNEATH AND OVER THE TOP, THE BULKHEAD PAPERED FROM THE BOTTOM OF THE TOP OPENING TO THE TOP OF THE BOTTOM OPENING. HEATERS ON BOTH SIDE RACKS.

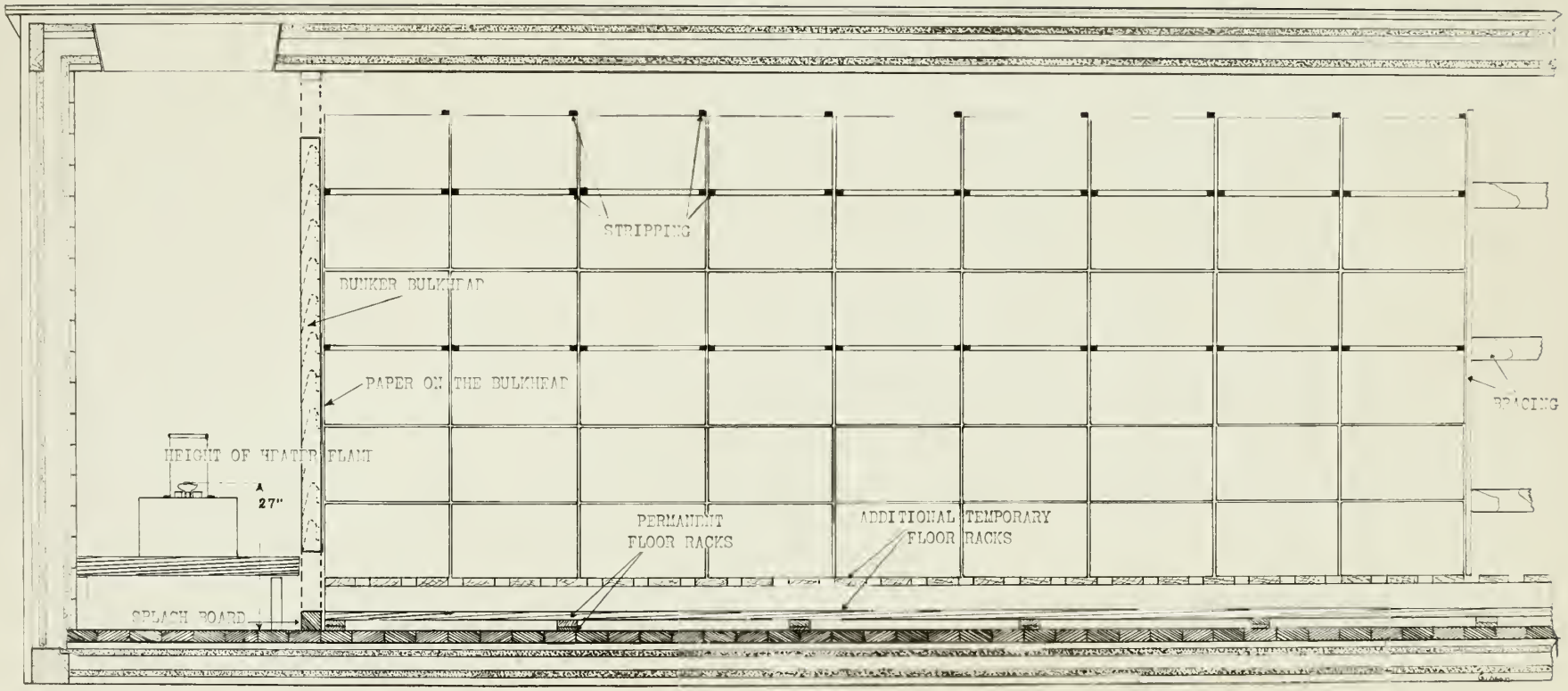


FIGURE 8 - SHOWING CAR E AS LOADED ON THE TEST TRIP RUN IN DECEMBER 1920. ADDITIONAL FLOOR RACKS ON TOP OF THE PERMANENT RACKS AND NO PAPER EXCEPT AT THE BULKHEAD.

tures were taken in boxes of apples located at the bottom, second, and top layers, nearest the north wall. Air circulation as effected by the lighted heaters was studied by releasing smoke within the car and observing its movement.

SPECIAL FEATURES

By means of the several methods outlined in this report, the following features were developed; (1) that by using the additional floor-racks the load is raised sufficiently from the floor to provide an unobstructed channel for the cold air to be drawn from the floor, unless an additional metal or wooden brace is found on top of the splashboard; (2) that when heaters rest on the ice grates, air is drawn at a level with the heater flames, 21 to 27 inches above the floor, but by lowering the heaters, the flames are placed on a plane nearer the floor and the cold air supply; (3) that by papering the bulkheads, the cold air is supplied to heaters from beneath the floor-racks; (4) that by papering across the top of the load, warm air is forced to the doorway before being drawn back to the heaters; (5) and that by placing paper on the floor-racks the return air circulation is confined to the space beneath the floor-racks.

RESULTS

The air circulation was studied by means of smoke rings during two of the trips with investigators riding within the cars. The best results were obtained in cars equipped as follows: when paper was placed on the face of the bunker bulkheads and across the top of the load except between the bracing; when ice grates were raised and heaters lowered to

the floor of the bunkers; when an open and unobstructed space underneath the floor-racks was provided for the cold air to reach the bunkers. From careful observations it was difficult to determine which of these features was the greatest contributor to the success of cars so equipped. It is believed, however, that all these features were important in securing a rapid circulation of air around the load.

Referring to Fig. 9, which shows the fruit temperatures at bottom of load in Cars "A", "D" and "E", it will be noted that all cars maintained practically the same temperatures from the beginning of the trip until 8:30 p.m. on December 18, when the heaters in forward ends of cars were lighted. From this time on, a considerable difference can be noted. The lighting of the heater in car "A" did not prevent a general decline in temperature, while in Cars "D" and "E" temperatures rose appreciably. Even after the second heater was lighted in the evening of the 19th, the same difference is noted. Shortly before noon on the 20th, in spite of continued fall of outside temperature, it was deemed advisable to turn down the heater flames in cars "D" and "E", as bottom layer temperatures in these cars (See Fig. 9) were higher than necessary. About 9 hours later, (7:30 p.m., Dec. 20) heater flames in car "A" were also turned down, temperatures in the top of the load in this car (See Fig. 9A) showing a rapid rise, reaching 70° at the bunker position. For the next five hours all heaters were operated alike. Shortly after midnight in the early hours of the 21st, the rear heater in car "D" was put out, and flames lowered in all the other heaters. No further change in heaters was made during the remainder of the trip, - about 36 hours. During this latter period, with equal amounts of

HEATER TEST TRIP

WENATCHEE, WASH. TO ST. PAUL, MINN.

DECEMBER 15th TO 22nd 1920.

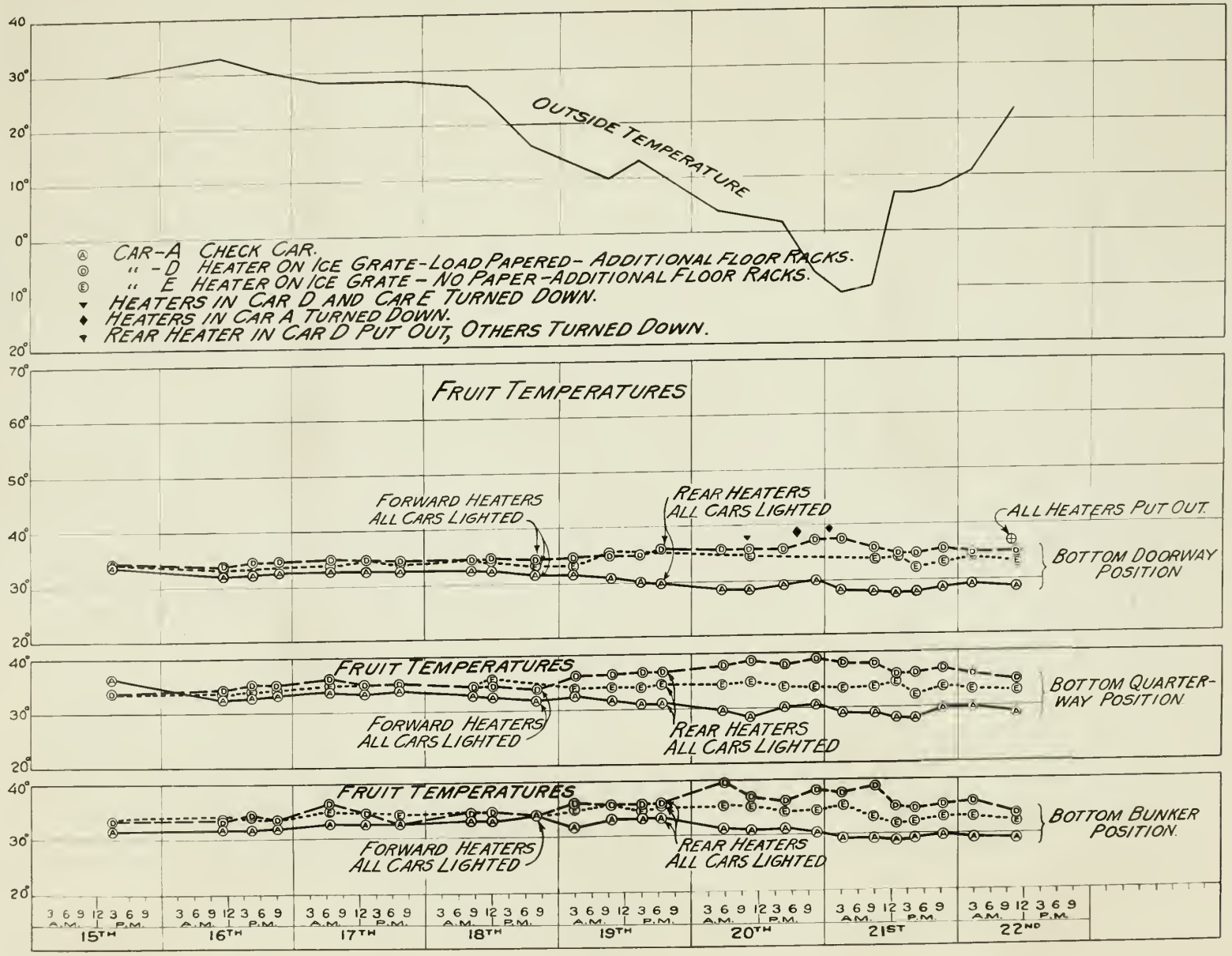


FIGURE 9

heat supplied to cars "A" and "E", car "E" maintained bottom layer temperatures 3 to 5 degress higher than car "A", (See Fig. 9) showing the effect of the additional floor rack in affording protection to the bottom of the load. Comparing cars "D" and "A", during the same period, "D" with only one-half the amount of heat supplied, maintained bottom layer temperatures 5 to 10 degrees higher than car "A", (See Fig. 9) showing in a pronounced manner the combined effect of the additional floor racks and the papering of the load. The effect of papering the load can be noted by comparing bottom layer temperatures in cars "D" and "E", (See Fig. 9) showing "D" temperatures 1 to 6 degrees higher than "E" with only one-half the amount of heat supplied.

Temperatures in top layers of the same cars, shown in Fig. 9A, are somewhat complicated by the different manipulation of the heaters. It is to be noted, however, that in both the cars ("D" and "E") equipped with additional floor racks, top layer temperatures did not rise nearly as high, by several degrees, as did those in the check car "A" not so equipped.

The effect of placing heaters on the bunker floor instead of on the ice grates can be readily seen by comparing the temperatures in car "C" with those in cars "A" and "D", which are shown in Figs. 10 and 10A. From the time the heaters were first lighted in all cars at 8:30 p.m. on Dec. 18 up to 7:30 p.m. on Dec. 20, practically two days, car "C" held temperatures in all bottom positions (See Fig. 10) from 5° to 11° warmer than the check car "A", and from 2° to 5° warmer than in car "D". From Fig. 10A it can be noted that the additional heating in the bottom layers was not accompanied by a corresponding increase in temperature in the top layers.

HEATER TEST TRIP

WENATCHEE, WASH. TO ST. PAUL, MINN.

DECEMBER 15TH TO 22ND 1920

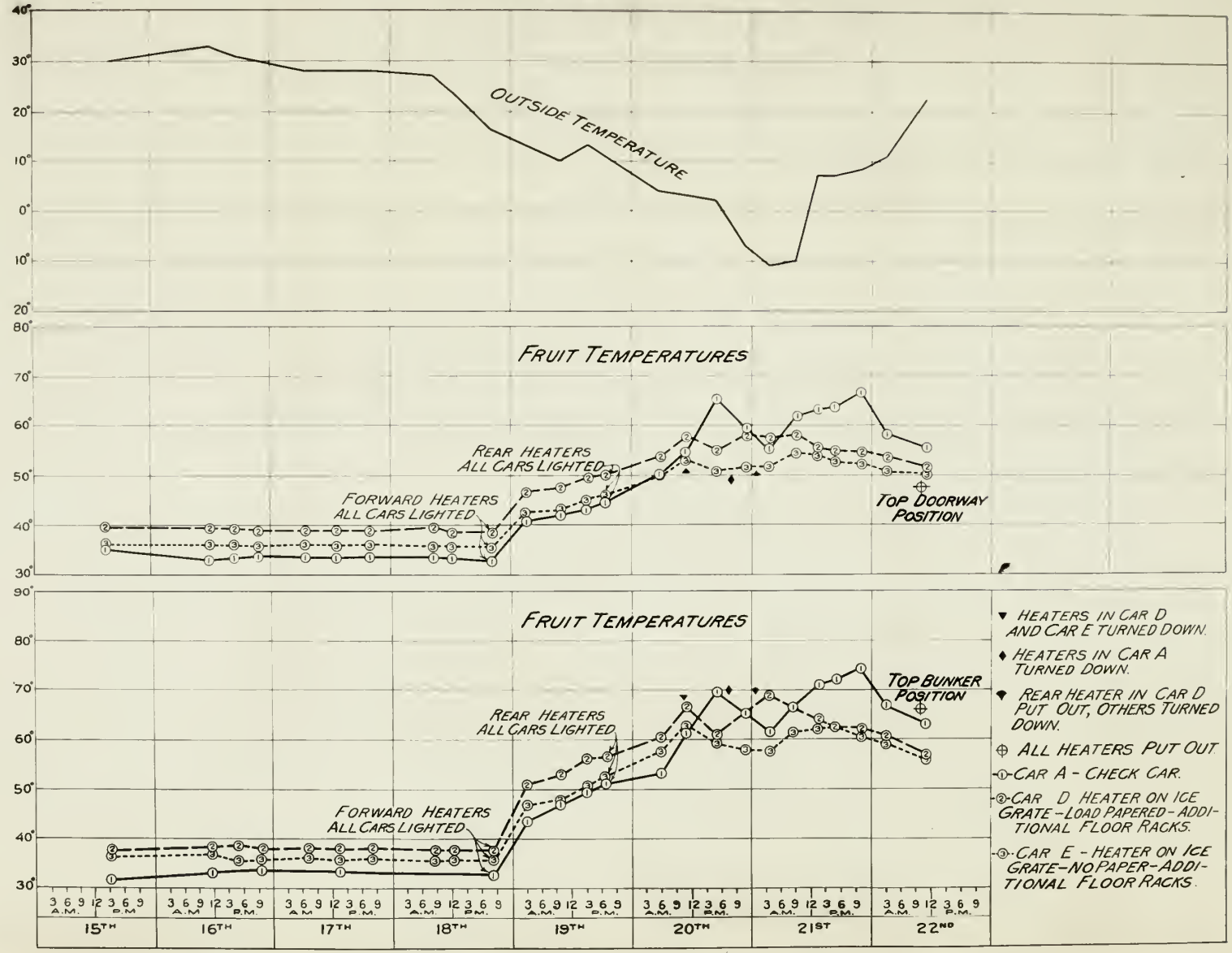


FIGURE 9A

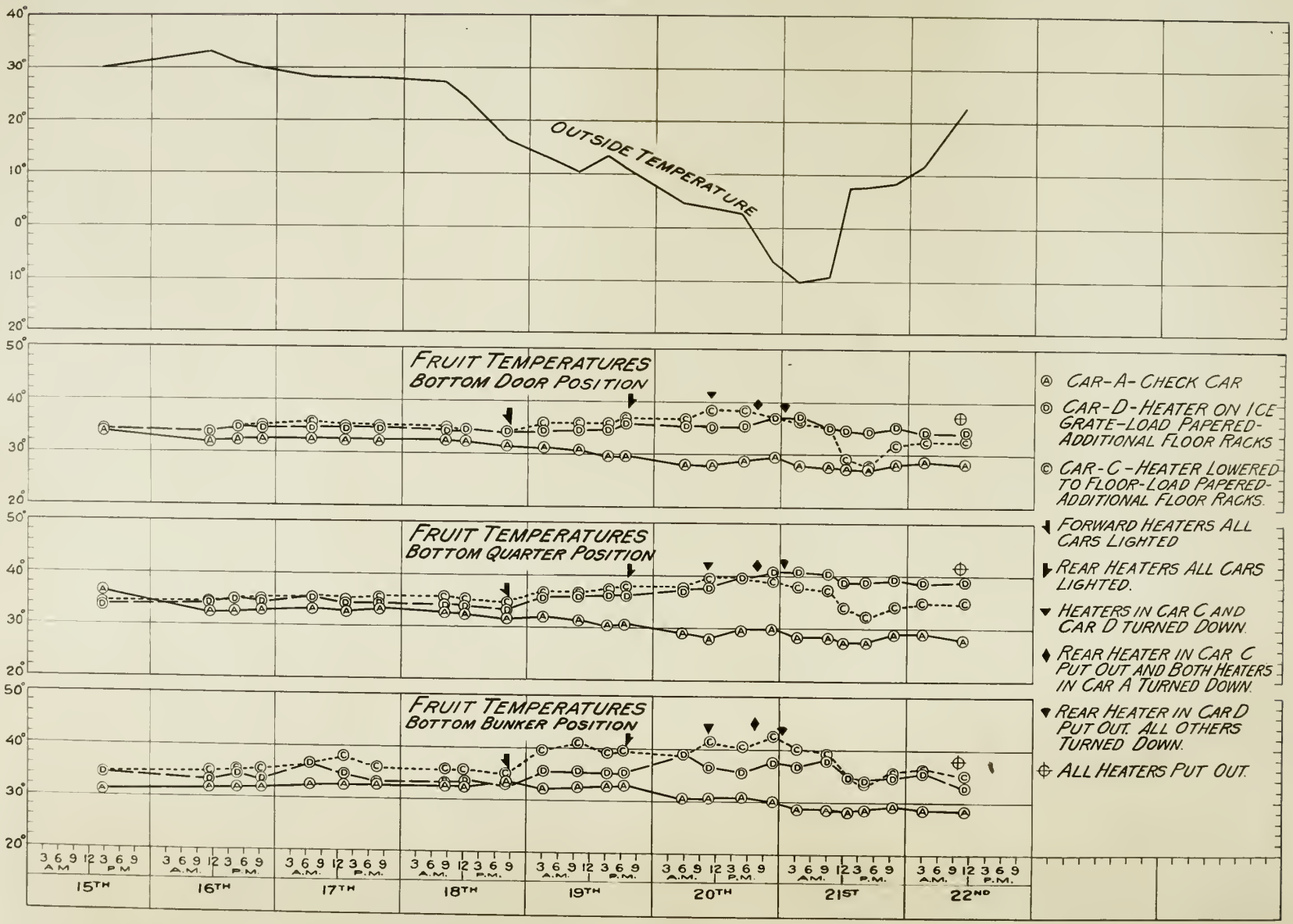

HEATER TEST TRIP
WENATCHEE, WASH. TO ST. PAUL, MINN.
DECEMBER 15th TO 22nd 1920
OUTSIDE TEMPERATURE
FRUIT TEMPERATURES
BOTTOM DOOR POSITION
FRUIT TEMPERATURES
BOTTOM QUARTER POSITION
FRUIT TEMPERATURES
BOTTOM BUNKER POSITION
Ⓐ CAR-A-CHECK CAR
Ⓓ CAR-D-HEATER ON ICE GRATE-LOAD PAPERED-ADDITIONAL FLOOR RACKS
Ⓒ CAR-C-HEATER LOWERED TO FLOOR-LOAD PAPERED-ADDITIONAL FLOOR RACKS.
FORWARD HEATERS ALL CARS LIGHTED
REAR HEATERS ALL CARS LIGHTED.
HEATERS IN CAR C AND CAR D TURNED DOWN.
REAR HEATER IN CAR C PUT OUT AND BOTH HEATERS IN CAR A TURNED DOWN.
REAR HEATER IN CAR D PUT OUT. ALL OTHERS TURNED DOWN.
ALL HEATERS PUT OUT.
15TH
16TH
17TH
18TH
19TH
20TH
21ST
22ND

FIGURE 10

HEATER TEST TRIP

WENATCHEE, WASH. TO ST. PAUL, MINN.

DECEMBER 15TH TO 22ND 1920.

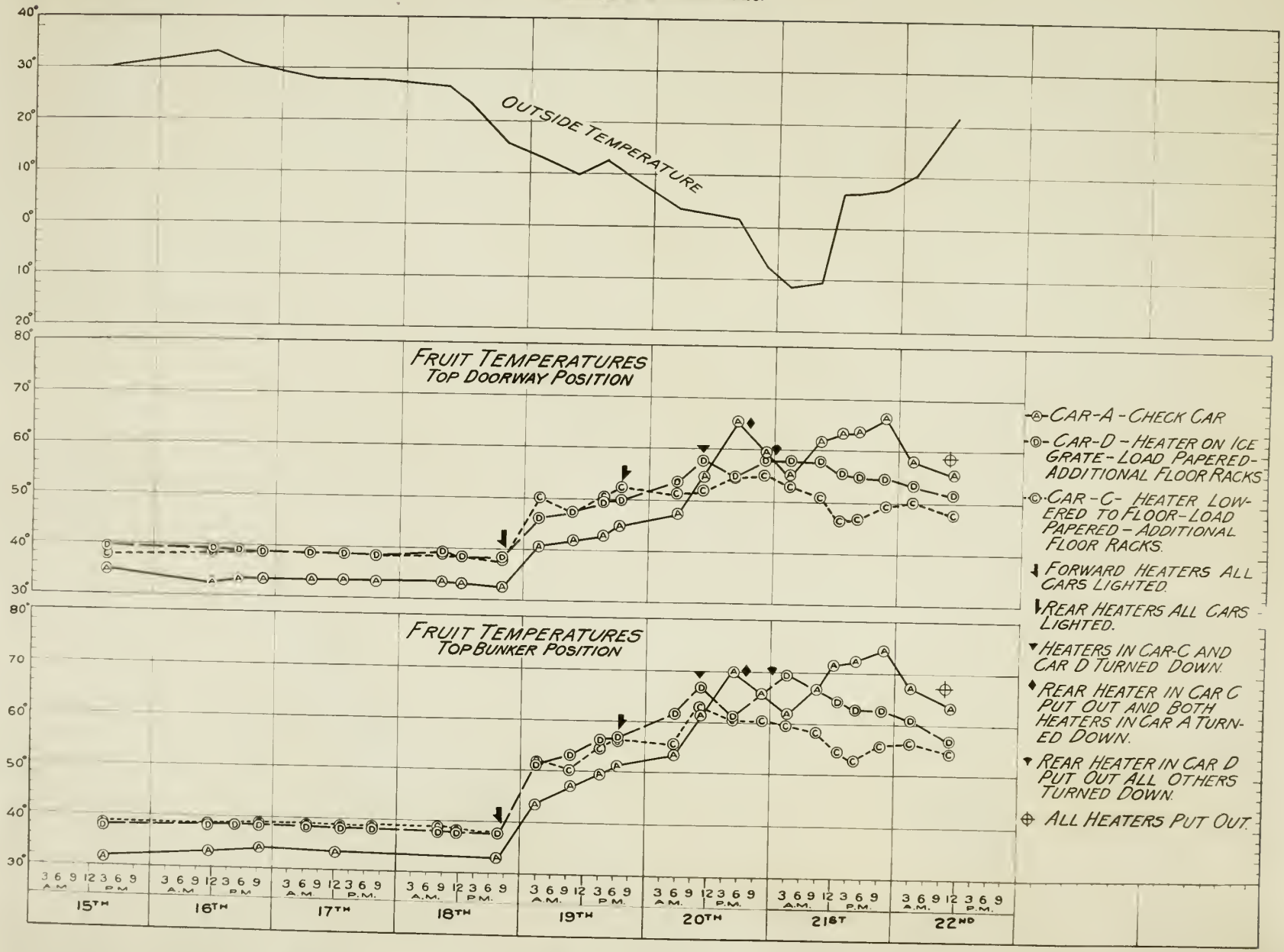

OUTSIDE TEMPERATURE
FRUIT TEMPERATURES
TOP DOORWAY POSITION
FRUIT TEMPERATURES
TOP BUNKER POSITION
A-CAR-A - CHECK CAR
D- CAR-D - HEATER ON ICE GRATE - LOAD PAPERED - ADDITIONAL FLOOR RACKS
C- CAR-C- HEATER LOWERED TO FLOOR - LOAD PAPERED - ADDITIONAL FLOOR RACKS.
FORWARD HEATERS ALL CARS LIGHTED.
REAR HEATERS ALL CARS LIGHTED.
HEATERS IN CAR-C AND CAR D TURNED DOWN.
REAR HEATER IN CAR C PUT OUT AND BOTH HEATERS IN CAR A TURNED DOWN.
REAR HEATER IN CAR D PUT OUT ALL OTHERS TURNED DOWN.
ALL HEATERS PUT OUT.
15TH
16TH
17TH
18TH
19TH
20TH
21ST
22ND

FIGURE 10A

During the remainder of the trip the results are so complicated by different operation of heaters in different cars that no definite conclusions can be drawn with regard to this part of the trip.

It can be seen that the use of paper assists in maintaining a higher temperature in the bottom or freezing zone of the car and that by combining the use of paper with the lowered heaters, these temperatures are raised still higher. At the same time the top layer temperatures are not correspondingly increased.

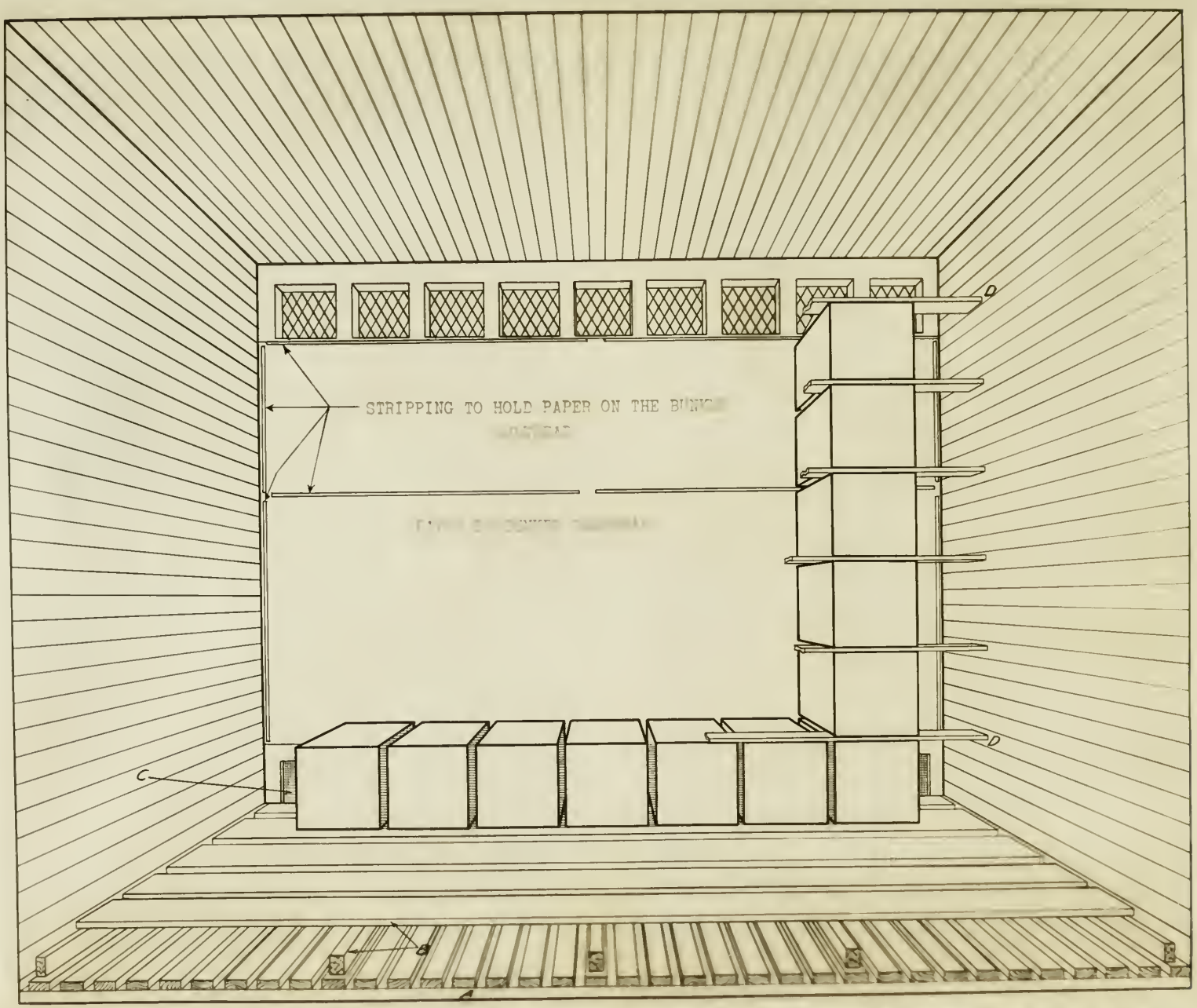
RECOMMENDATIONS

While the work during the past winter was handicapped because of the rather mild weather, the investigations show that by applying simple and practical principles of air circulation in the heating of a refrigerator car, decidedly better control of fruit temperatures can be obtained.

In view of the serious freezing losses incurred by carriers and shippers in recent years, and the vital importance of taking immediate action to minimize such losses in the future, the following recommendations are made. Further investigations may develop the necessity of some modifications of these recommendations.

An unobstructed channel beneath the load should be provided so as to permit free movement of air back to the heaters. Floor racks with longitudinal stringers not less than 4" high are necessary.

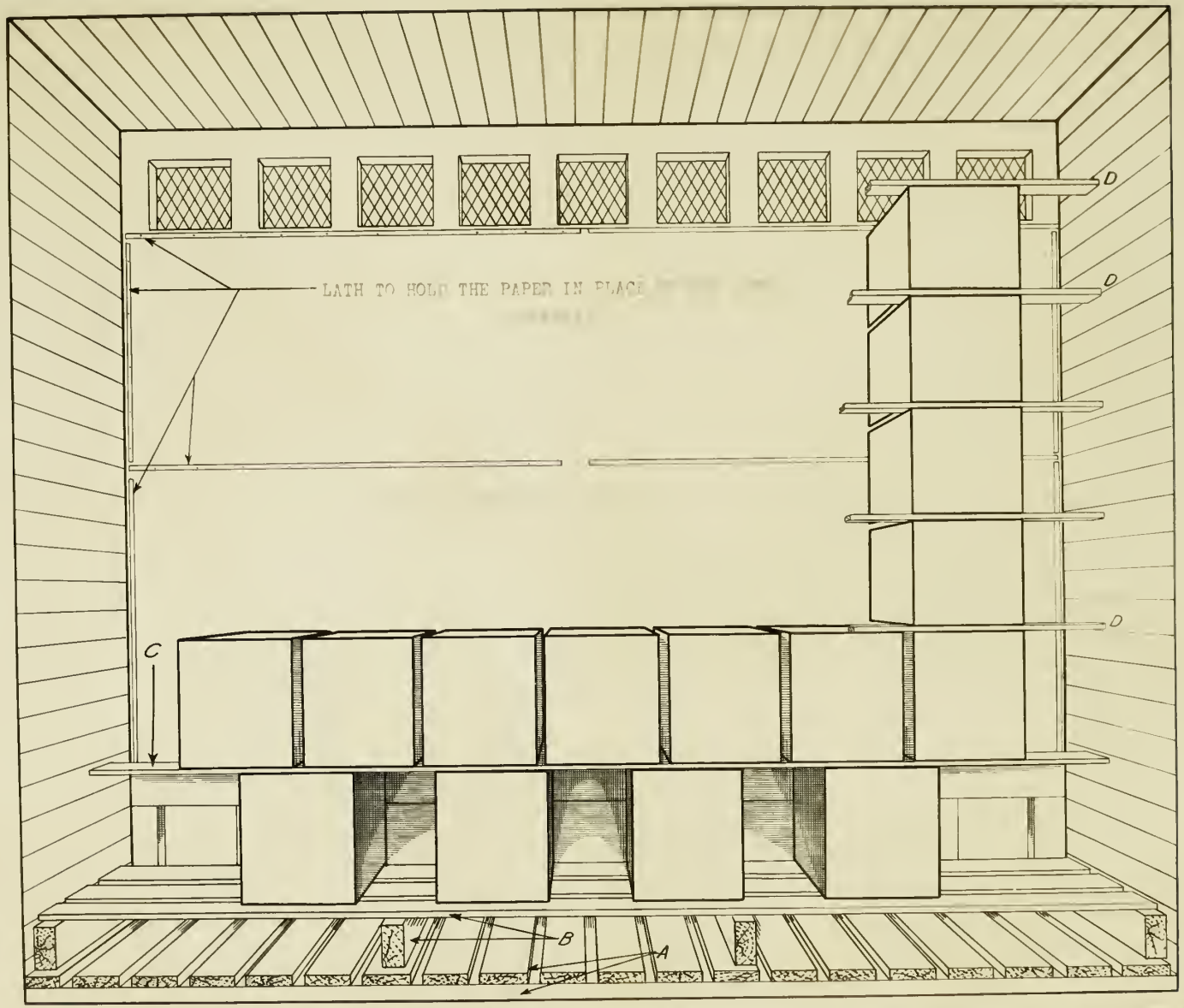
The addition of floor racks to the standard or common style of loading (See Fig. 11) does not provide the necessary space for air movement in cars constructed with undesirable features, such as splashboards of the same height as floor racks, or additional metal braces on top of


STRIPPING TO HOLD PAPER ON THE BUNC
D
D
C

the splash boards, as shown in Fig. 3. In view of the fact that the majority of shippers give the construction features of the car no consideration when loading, it is recommended that the first four boxes placed in each end of the car be arranged according to the plan as shown in Fig. 12. The first or bottom layer in the stacks next to the bunkers consists of only four boxes, so spaced that bottom boxes in the second stack cannot slip into the spaces between the boxes in the first stack. This precaution must be taken to prevent shifting of the bottom layer of the load. On top of the first four boxes are nailed two 1" x 6" boards, (See Fig. 12) to hold the remaining 5 layers of the stacks next to the bunkers. This plan will reduce the load to 750 boxes which, however, is still in excess of the minimum weight requirements. Another method of loading consists in using a false form as shown in Fig. 5 in place of spacing the four boxes next to the bunker. However, this method would cut the load to 742 boxes, as one entire layer would have to be left off from stacks next the bunkers.

Paper should be placed across the top of the load and extend to the bracing in each end of the car so that warm air from the heaters will move to the center of the car before returning to the heaters. Floor racks should not be papered at the center of the car between the bracing nor between the load and side walls.

All open types of bulkheads should be papered from the bottom of the top opening near the ceiling of the car to the top of the first layer of boxes next to the bunkers. All bunker bulkheads of the solid type, with open spaces at the top and bottom only, need not be papered.


LATH TO HOLD THE PAPER IN PLACE
D
D
D
C
B
A

If possible, the ice grates should be raised and heaters placed on the floor of the bunkers, thereby providing a lower plane from which the heaters can draw their supply of cold air.

When operating under heater service the lading should not be spaced as for refrigeration service. The lading should be stacked solid leaving spaces between the load and side walls, between load and ceiling, between load and car floor and between the bracing.